Unit A Conclusion

When you began this unit you were asked to think about the connections between consumer goods and the environment. You learned that all of these products begin as raw materials that come from natural resources. To produce a particular item for consumers, the raw materials are chosen based on their chemical and physical properties.

Solutions are an excellent medium for chemical change because when a substance becomes dissolved, some of its chemical bonds are broken. The reactions between metal atoms and metal ions in solutions involve the gain and loss of electrons (reduction and oxidation).

A refinery uses different boiling points to separate the various types of hydrocarbons from the complex mixture called petroleum. Since these hydrocarbons become the main ingredients in specialized fuels and plastics, you can see what people mean when they say that society is based on a carbon-based economy. You will have an opportunity to explore other aspects of this idea as you study transportation safety in Unit B.

Career Profile

Metallurgical Engineer

Like lots of curious kids, Nalaine grew up asking a lot of questions. "When I was young, I found that I was always asking myself why," she recalls. As a kid, she was also fascinated by how stuff worked, "especially the industrial machinery at the sawmill where my dad worked." When Nalaine's dad had to go to work on a Sunday, she would tag along with him just to examine all the different machinery at the sawmill.

Nalaine always knew that when she left high school she'd be working towards a degree in engineering. "It just seemed like a normal path for me, and I wanted to be able to go back and work for my people." The difficult part was trying to figure out what field of engineering she should study. "I wanted to go into environmental engineering but found that [at the time] not many universities offered it." With a little contemplating, the influence of her high school math teacher, and an interest in metal and materials, she decided to pursue a degree in Metallurgical Engineering. She recalls, "My math teacher made me enjoy math and learning so much that I was eager to continue on with my schooling so that I could learn more."

Nalaine graduated from the University of British Columbia with a bachelor's degree in Metallurgical Engineering. She explains that even though "university was difficult at times, sometimes the course load was a bit heavy; it was an excellent learning experience." Her advice to students, "It is extremely important to practise good time-management skills, do a lot of reading on your own, and always try to make a connection between science and math and everyday life."

For Nalaine, the best thing about school was meeting new people. "I still keep in contact with a lot of the people I met in school. Most of them have gone on to excellent and exciting careers with big companies."

Nalaine has also gone onto a very exciting career working as a Metallurgical Engineer at the Hudson Bay Mining and Smelting Co. in Flin Flon, Manitoba. Nalaine's job is to monitor, optimize, and implement changes that will help improve the plant's performance. A lot of her work consists of testing, troubleshooting, data reporting, and writing reports and procedure manuals.

Outside of work, Nalaine enjoys kayaking, skiing, playing tennis, and travelling. She would also like to go back to school to pursue a master's degree in Environmental Engineering. For Nalaine, her "goal as an engineer is to always protect our Mother Earth." She would like to encourage young First Nations students to go to university and pursue a degree in engineering or the sciences so that they "can help protect our environment" and work to create self-sufficient communities.

Unit A Review Questions

1. Which term—*solution*, *solute*, or *solvent*—best matches each of the following substances?
   - **a.** sucrose (table sugar)
   - **b.** water
   - **c.** sports drink
2. Use the following list to answer questions 2.a. and 2.b.

   I. hydrogen peroxide, $H_2O_2(aq)$
   II. hydrochloric acid, HCl(aq)
   III. salt water, NaCl(aq)
   IV. ammonia, $NH_3(aq)$

   - **a.** The two electrolyte solutions are _____ and _____.
   - **b.** The two non-electrolyte solutions are _____ and _____.
3. At the particle level, describe how water molecules act to change the structure of the crystals of a solid ionic compound to form an electrolytic solution.
4. Use a simple, labelled diagram to highlight the main features of each of the following types of solutions.
   - **a.** an electrolytic solution
   - **b.** a non-electrolytic solution
   - **c.** a concentrated solution
   - **d.** a dilute solution
5. Read the following descriptions of four chemical reactions.

   Reaction A: Copper sheets oxidize and lose their shine.
   Reaction B: Hydrogen ions in solution react to form a molecule of hydrogen gas.
   Reaction C: Iron metal rusts to form iron(II) oxide.
   Reaction D: A nickel(II) ion is electroplated at the cathode of an electrolytic cell.

   Complete the following chart for each of the reactions.

Reaction	Half-Reaction for the First Element Mentioned	Oxidation or Reduction	Number of Electrons Gained or Lost
A			
B			
C			
D			

6. In this unit you made an extensive use of the activity series for metals and metal ions. Summarize the uses of this activity series.

7. Examine the following balanced chemical equation:

$$2\ Mg(s) + O_2(g) \text{ Æ } 2\ MgO(s)$$

a. Identify the chemical substance being oxidized.
b. Identify the chemical substance being reduced.
c. Identify any spectators.
d. Determine the number of electrons gained by each atom or ion.
e. Determine the number of electrons lost by each atom or ion.

8. Examine the following balanced chemical equation:

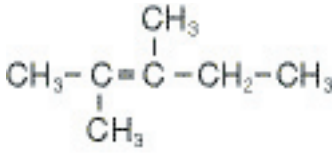
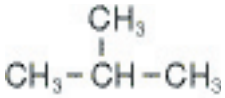
$$2\ Ag(s) + H_2SO_4(l) \text{ Æ } Ag_2SO_4(aq) + H_2(g)$$

a. Identify the chemical substance being oxidized.
b. Identify the chemical substance being reduced.
c. Identify any spectators.
d. Determine the number of electrons gained by each atom or ion.
e. Determine the number of electrons lost by each atom or ion.

9. Determine whether the following species could undergo oxidation, reduction, or both.

a. a hydrogen ion, $H^+(aq)$
b. a gold ion, $Au^+(aq)$
c. a silver ion, $Ag^+(aq)$

10. Complete the following table.

Name of Compound	Chemical Formula	Condensed Structural Diagram	Alkane, Alkene, or Alkyne	Saturated or Unsaturated
2,2-dimethylpentane				
4-propyloctane				
3-octene				
	$C_7H_{12}(l)$			
2-ethyl-1-hexene				
	$CH_4(g)$			
				
				

11. Draw the condensed structural diagram for 4,4-diethyl-2-hexyne. Describe the process used to draw the diagram.

12. Complete each of the following calculations by showing all of your steps.

a. Calculate the molar concentration of a solution prepared by adding 150 mL of water to 25.4 g of silver nitrate, $AgNO_3(aq)$.

b. Calculate the number of moles of solute dissolved in 0.050 L of a 0.392-mol/L silver nitrate solution, $AgNO_3(aq)$.

c. The maximum concentration of lead in drinking water is 0.010 ppm. A 4.00-kg sample of contaminated well water was found to have twice this concentration of lead. Calculate the mass of the lead dissolved in the water.

d. In addition to copper, trace amounts of other metals are often recovered at copper mines. The concentration of silver found in the ore of a copper mine is 58 ppm. Calculate the mass of ore that would have to be mined to yield 1.00 kg of silver.

13. Ammonia is a very useful reagent for many reactions. One way of making ammonia is to react nitrogen gas with hydrogen gas.

$$N_2(g) + 3\ H_2(g) \text{ Æ } 2\ NH_3(g)$$

You have 20.0 mol of nitrogen.

a. How many moles of ammonia could you make?

b. How many moles of hydrogen gas would you require to react with the nitrogen?

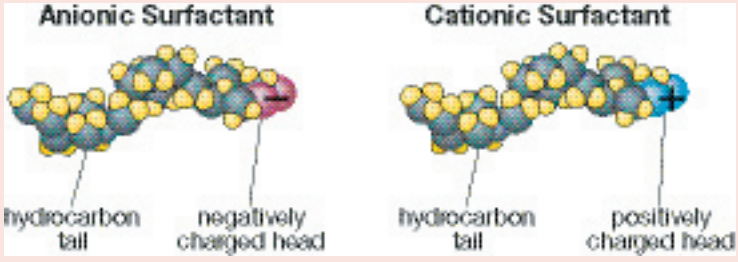
Use the following information to answer questions 14 to 18.

Case Study: The Chemistry of Hair Conditioners

When you rinse shampoo out of your hair, you also remove oils that act to protect your hair. A hair conditioner replaces these oils with a protective coating. Although some hair conditioners are applied and then left on wet hair, most conditioners are also rinsed out of the hair. How can the protective coating be left on the hair when the other ingredients of the conditioner are rinsed away?

Part of the answer to this question is found in the structure of hair itself. The main protein in hair is keratin. An interesting property of the keratin in hair is that its molecular structure tends to have a high percentage of negative charges on its outer surface. This means that the outer surface of each shaft of hair tends to have a slightly negative charge, even after it's been washed with shampoo.

This is why the manufacturers of hair conditioners use substances in their products called surfactants—short for "surface active agents."



Surfactants work because one end of these long molecules consists of a tail of hydrocarbons that can attach itself to oily substances. At the other end of these molecules is a head that can be ionized. If the head of the surfactant carries a negative charge, it is called anionic. If the head carries a positive charge, the surfactant is called cationic.

As the following example indicates, conditioners usually consist of a group of cationic surfactants mixed with other ingredients in a water-based solution.

INGREDIENTS IN BRAND Y HAIR CONDITIONER

Ingredient	Volume (mL)	Function
water	465.5	acts to dissolve the other ingredients
cyclomethicone and dimethiconol solution	10.5	an oil soluble blend of compounds that holds silicone in solution until it can be released onto the hair
distearyldiammonium chloride solution	7.0	cationic surfactant—helps second ingredient attach to hair
cetyl alcohol solution	6.0	ingredients work to keep the oil-based and water-based parts of the solution from separating
sorbitan oleate solution	5.0	
stearyl alcohol solution	4.0	
polysorbate-85 solution	2.0	
Total	500.0	

The cationic surfactants play a key role in hair conditioners. The charged head of the surfactant is attracted to the hair while the long tail helps carry the oil-based ingredients that give the hair its shine.

14. Identify the ingredient in the hair conditioner that could be classified as the solvent.

15. Identify an ingredient in the hair conditioner that could be classified as a solute.

16. Explain how neutral water molecules could be attracted to the charged head of a cationic surfactant. Sketch and label a diagram to support your answer.

17. As explained in the information, the outer surface of a hair has a slight negative charge.

a. Explain the significance of the charge along the length of the hair to the action of the cationic surfactants in bringing a new protective coating to a hair.

b. Explain why conditioned hair is less likely to stand on end and "fly away."

18. Calculate the percent by volume concentration of the following ingredients in the hair conditioner.

a. distearyldiammonium chloride

b. cetyl alcohol

c. polysorbate-85

19. Balance each of the following reactions.

a. $SnCl_2(aq) + Al(s) \rightarrow AlCl_3(aq) + Sn(s)$

b. $Au(NO_3)_3(aq) + Ag(s) \rightarrow AgNO_3(aq) + Au(s)$

c. $HNO_3(aq) + Cu(s) \rightarrow Cu(NO_3)_2(aq) + H_2(g)$

d. $Zn(s) + H_2SO_4(aq) \rightarrow H_2(g) + ZnSO_4(aq)$

20. If you react chlorine gas with sodium metal, you can produce sodium chloride.

$$Cl_2(g) + 2\ Na(s) \rightarrow 2\ NaCl(s)$$

a. State the chemical substance that is being oxidized.

b. State the chemical substance that is being reduced.

c. Determine the number of electrons transferred in the reaction.

d. If 75.0 mol of sodium reacted with a sufficient amount of chlorine gas, how many moles of chlorine gas will be required?

21. A student performed an experiment on platinum metal and collected the following data:

$Pt(s) + Ag^{+}(aq)$ Æ no reaction

$Pt(s) + Fe^{2+}(aq)$ Æ no reaction

According to the data, where should solid platinum, Pt(s), and its ion, $Pt^{2+}(aq)$, appear in the activity series for metals and metal ions?

22. Use the activity series to predict whether each combination of reactants will result in a spontaneous reaction.

a. copper metal and chromium(II) ion
b. zinc metal and hydrochloric acid
c. silver metal and nitric acid
d. silver ion and nickel metal

23. List some of the methods used to prevent the corrosion of metals. Briefly explain how these methods prevent the oxidation of the metal being protected.

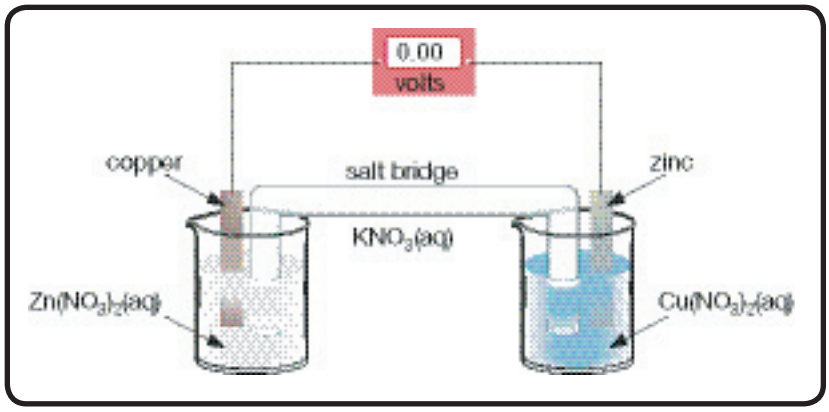
24. An automobile manufacturer plans to build a corrosion-proof body for a car. The car's body will be made entirely from plastic. Will the use of plastic in the car's body prevent damage from corrosion? Suggest advantages and disadvantages of this design.

25. The following cell notation describes a voltaic cell:

$Mg(s) \mid Mg^{2+}(aq) \mid\mid Ag^{+}(aq) \mid Ag(s)$

Draw a diagram of this voltaic cell. Label the anode, cathode, voltmeter, and salt bridge. Also label the direction of the flow of electrons, anions, and cations within the cell. Assume that potassium nitrate, $KNO_3(aq)$, is used in the salt bridge.

26. The following diagram shows a voltaic cell that a student set up in a lab.



Observations from this cell:

- The voltage output is zero.
- The solution of $Cu(NO_3)_2(aq)$ is becoming less blue as time goes by.
- The mass of the zinc electrode has increased since the experiment began.

a. Suggest a reason for the change in the mass of the zinc electrode in the cell.
b. Suggest a reason why the cell was not able to produce a voltage.

27. Locate the video clip called "Career Profile: Ceramic Artist" on the Science 20 Textbook CD. This segment describes how chemistry is used by a potter to create works of art. Watch this video, and then answer the following questions.

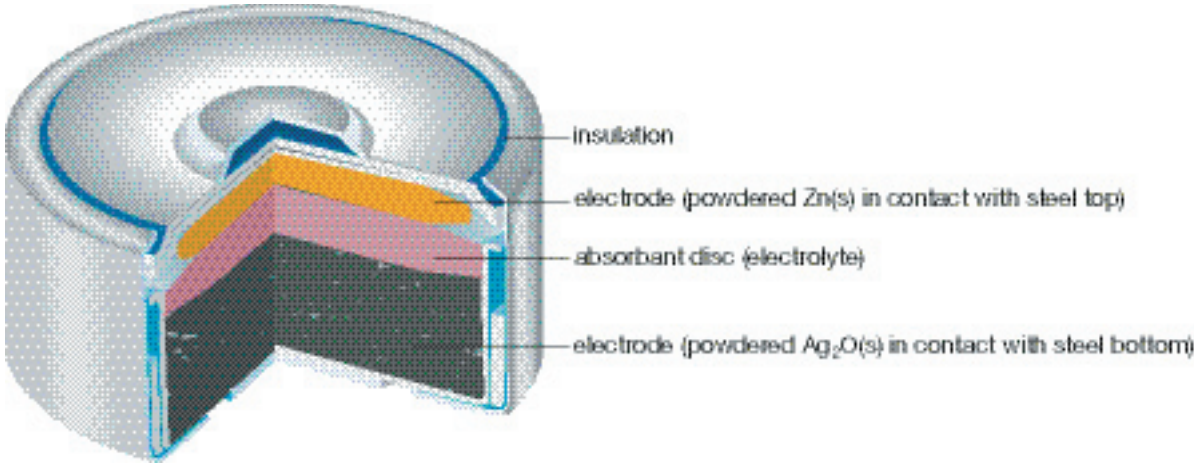
a. Describe the chemical composition of the clay used by a ceramic artist.

b. List the compounds used to give colour to a glaze.

c. Consider the list that you generated in 27.b. Identify the category of matter that applies to all the compounds on your list.

d. Describe how the compounds used in glazes are prepared to be applied to the clay body.

28. Some specialized electrical devices, such as pacemakers, require a miniature cell that can maintain a constant voltage throughout its useful lifetime. In these devices, silver-zinc button cells are often used.


insulation
electrode (powdered Zn(s) in contact with steel top)
absorbant disc (electrolyte)
electrode (powdered $Ag_2O(s)$ in contact with steel bottom)

Although the chemical reactions within these cells are complex, they can still be categorized as oxidation and reduction.

Oxidation and Reduction in a Miniature Silver-Zinc Button Cell

Reaction 1: $Ag_2O(s) + H_2O(l) + 2e^- \rightarrow 2\,Ag(s) + 2\,OH^-(aq)$
Reaction 2: $Zn(s) + 2\,OH^-(aq) \rightarrow ZnO(s) + H_2O(l) + 2e^-$

a. Classify Reaction 1 as being either an oxidation or a reduction reaction. Support your answer.

b. Is the powdered $Ag_2O(s)$ in contact with the steel bottom acting as the anode or the cathode in this cell?

c. Classify Reaction 2 as being either an oxidation or a reduction reaction. Support your answer.

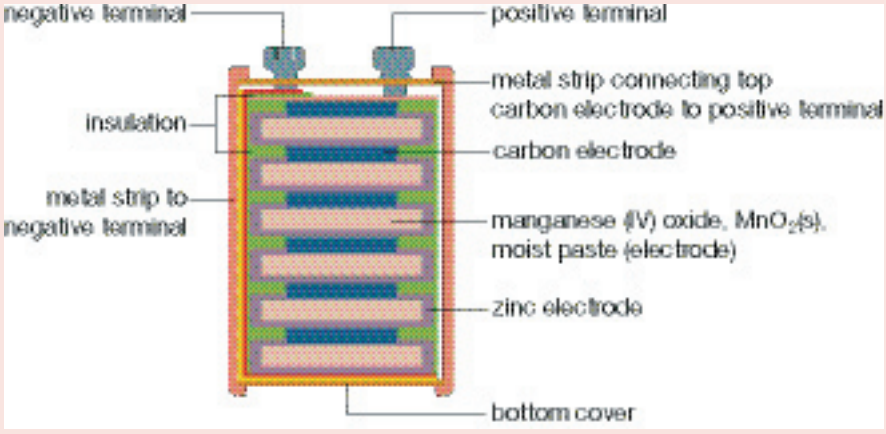
d. Is the powdered zinc, Zn(s), in contact with the steel top acting as the anode or the cathode in this cell?

e. Would electrons leave the top of this cell and flow through an external circuit or would they leave the bottom of this cell?

Use the following information to answer questions 29 to 31.

Although a single zinc chloride cell can provide 1.5 V, smoke detectors require a higher voltage. For applications such as this, the six cells are combined in a single package to provide 9.0 V of output. Refer to the cross sectional diagram given.

Each cell within this device adds energy to the current of electrons that flows to the circuitry of the smoke detector. The chemical reactions that occur within each cell are summarized as follows:



Oxidation and Reduction Within Each Cell

Oxidation Reaction: $Zn(s) \rightarrow Zn^{2+} + 2e^-$
Reduction Reaction: $2\,NH_4^+(aq) + 2\,MnO_2(s) + 2e^- \rightarrow Mn_2O_3(s) + 2\,NH_3(g) + H_2O(l)$

29. Identify the proper name for the type of device shown in the illustration.

30. Consider the oxidation reaction that occurs within each cell.

a. Use this reaction to determine whether the zinc electrode is acting as the anode or the cathode.

b. Carefully examine the cross sectional diagram. Explain how this diagram verifies your answer to question 29.a.

31. Consider the reduction reaction that occurs within each cell.

a. Explain why both the manganese and the ammonium are considered to be reduced in this reaction.

b. If the reduction half-reaction for the manganese(IV) oxide were to be placed in the activity series for metals and metal ions, would it appear above or below the reduction half-reaction for zinc? Explain.

32. Draw an electrolytic cell that would be able to plate nickel onto an iron drill bit. In your diagram include the following:

- electrolyte solution and label its contents
- anode
- cathode
- power source
- direction for electron flow

33. The compound 3-ethyl-3-methyl-2-pentyne cannot exist. Use the name of the compound to draw a condensed structural diagram that will explain why this compound could never exist.

34. **a.** Write a balanced chemical equation to show one possibility in the cracking of decane.

b. Properly name the products of your cracking reaction.

35. Write a balanced chemical equation to describe each reaction.

a. the combustion of butane

b. the combustion of 2,2-dimethylhexane

c. the hydrogenation of 3-hexene

36. Draw a series of diagrams to illustrate the polymerization of 2-butene.

37. Many nutritionists recommend sardines as a healthy food. Although this food is a good source of many important nutrients, it is not a perfect food due to the presence of some less desirable substances.

a. Saturated and unsaturated fats are listed in the nutrition facts. Explain what these terms mean in terms of the carbon chains that make up these substances.

b. Identify at least two items listed in the nutrition facts that indicate that this is a healthy food choice.

c. Identify at least two items listed in the nutrition facts that are less desirable because they are not associated with good health.